mean declination is concordant indicating no vertical-axis rotation. ChRM directions were determined from all 28 sites collected from a section in the northeastern portion of the Qaidam basin and these directions pass both fold and reversal tests. The mean declination is concordant indicating no vertical-axis rotation. In the Maza Tagh of the central Tarim basin, samples from half of the 55 sites collected from Miocene red sedimentary rocks yielded ChRM directions. A positive fold test suggests prefolding magnetization. The mean declination indicates $22.1^{\circ} \pm 6.1^{\circ}$ clockwise vertical-axis rotation. However, interpretation of this result is complicated by the structural setting of the sampled section near the termination of a thrust fault which has substantial curvature in map view. The overall pattern of paleomagnetically determined vertical-axis rotations suggests: (1) the Qaidam basin, Altyn Shan, and the Altyn Tagh Fault have not rotated since the Oligocene; (2) the Nan Shan-Qilian Shan area have experienced a regional 30° clockwise rotation. Further analysis of samples from the Qilian Shan are underway to test the regional significance of this clockwise rotation.

T62D-10 1345h POSTER

Magnetostratigraphy of Tertiary Sediments from the Hoh Xil Basin: Implications for the Cenozoic Uplift History of the Tibetan Plateau

Xixi Zhao[1] (831-459-4847; xzhao@es.ucsc.edu)

Zhifei Liu[2]

Chengshan Wang[3]

Shun Liu[3]

Haishen Yi[3]

[1]Center for Studies of Imaging and Dynamics of the Earth (CSIDE) and Earth Sciences Department, University of California, 1156 High Street, Santa Cruz, CA 95064, United States

[2]Laboratory of Marine Geology, Tongji University, 1239 Siping Road, Shanghai 200092, China

[3]Institute of Sedimentary Geology, Chengdu University of Technology, No. 1 Erxianqiao Dongsalu, Chengdu 610059, China

We conducted an integrated paleomagnetic and stratigraphic study on a 5,452.8 m thick sedimentary sequence of the Hoh Xil basin, north of the Qinghai-Tibet Plateau to obtain a chronostratigraphic framework for these sediments. A total of 1269 individual oriented paleomagnetic samples (spaced at stratigraphic intervals) were collected from 6 measured sections in the Hoh Xil basin. Magnetic directions in these samples were obtained by progressive thermal (mainly) and alternating-field demagnetization experiments. Most samples exhibit two components of magnetization. The lower unblocking temperature component is an overprint resembling the geocentric axial dipole field direction at the sampling locality. The most stable, characteristic remanence (ChRM) appears to be an early chemical remanent magnetization residing mainly in hematite. The positive results of fold and reversal tests indicate that the ChRM is a record of the paleomagnetic field close to the time of formation of these sediments. Further evidence for the magnetization of these sediments acquired close to their time of deposition is the fact that patterns of magnetic reversals can be matched with the established polarity time scale. On the basis of distinct interval of magnetic reversal zones and biostratigraphic datums, 14 magnetozones can be recognized at the Hoh Xil Basin that range from Chrons C10 to C24. Sedimentation rates derived from the magnetostratigraphy suggest that a sharp increase in basin subsidence is recorded near 40 Ma. We interpret this increased sedimentation as a response to crustal deformation caused by the final stage of India-Asia collision during the middle Eocene (Chron C18).

T62D-11 1345h POSTER

Cenozoic Tectonic Evolution of the Turfan Basin of East Tian-Shan: New Cretaceous and Tertiary Paleomagnetic Results

Baochun Huang[1] (bchuang@mail.c-geos.ac.cn)

Rixiang Zhu[1] (rxzhu@mail.c-geos.ac.cn)

Tianshui Yang[2]

Meixiang Bai[3]

[1]Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100101, China

[2]Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China

[3]Institute of Geology, Bureau of Seismology of Xijiang, Urumqi 830011, China

In order to contribute our understanding to the Neotectonics of blocks of the Tibet and central Asia, we collected orientated paleomagnetic samples from Cretaceous and Tertiary red beds from the Turfan intramontane basin of East Tian-Shan, Northwest China. Thermal demagnetization of the Paleogene and Miocene rocks isolated a high-temperature component that we interpret as the primary magnetization on the basis of positive fold and reversal tests. However, the high-temperature component isolated from the Cretaceous rocks has a syn-folding origin, acquired at 52% of complete unfolding, which is a remagnetization related to the Hami Movement during the late Pliocene. Similar to the previous studies of Tertiary formations from central Asia, the inclinations we obtained are significantly shallower than the magnetic field computed from the Eurasian APWP at the appropriate ages 20 - 60 Ma for the Paleogene and Neogene rocks. The AMS measurement of a total of 264 samples show weak anisotropy degrees, with over 85% samples of the order of less than 5%, confirming that the effect of magnetic fabric in most of these beds can generally be neglected. Comparison with the available Cretaceous paleomagnetic results from assemblage of Tarim, Junggar and Turfan basin, a significant post-Cretaceous local rotation has occurred in the Turfan basin. On the other hand, paleomagnetic pole corresponding to the late Pliocene remagnetization shows a same order of latitudinal differences as the Cretaceous pole with respect to the reference Eurasia. The tectonic implication of these results will further be discussed.

T62D-12 1345h POSTER

Tertiary Growth of the Tibetan Plateau from Cenozoic Deposition and Deformation of Red Beds of the Dogai Coring Fold-Thrust Belt, Central Tibet

Matthias C Dassinnies[1] (49-03731-39-3758; dassinni@merkur.hrz.tu-freiberg.de); M A Edwards[1] (edwards@geologie.uni-wuerzburg.de); L Ratschbacher[1]; C Bauer[1]; WSF Kidd[2]; Wu Zhenhan[3]; INDEPTH Team

[1]Asian Tectonics Research Unit, Institut fr Geologie, TU Bergakadamie Freiberg, Freiberg D-09596, Germany

[2]Department of Geological Sciences, SUNY, Albany, NY 12222, United States

[3]Chinese Academy of Geological Sciences, Baiwanzhuang Rd, Beijing 100037, China

Cenozoic fluviatile red bed sequences (e.g. Fenghuoshan - Kidd et al., 1988; Hoh Xil - Zhang and Zheng, 1994) occur throughout Central and Northern Tibet, mainly clustered along a belt south of the Kun-Lun. Depocentre migration, earthquake-induced sediment liquification, and ubiquitous post-lithification deformation features indicate that deformation was typically syn- to post-depositional (Liu et al., 2000, and this study). Our field mapping, cross-section, palaeocurrent and fault-slip analyses, remote sensing, and detrital grain geochronology (AFT) outline a Cenozoic, ~70 km x 200 km, fold-thrust belt north of Dogai Coring Tso (DGC) as part of a larger belt extending >600 km W-E and continuing E to the Fenghuo Shan. Three across-strike traverses reveal 100 metres-, to km-thick thrust sheets. Green and red silts, sands and (rare) conglomerates form open to tight folds on N-dipping thrust surfaces. For remotely sensed structural interpretation, sharpness enhancement and directional filters were employed to aid resolution of linear structures. This led to preferential displaying of structural features at higher angles to bedding. The principal limitation encountered using these techniques is the geometric ordering of pixel jogs causing a potential bedding mimic effect. For the most part, however, we have successfully interpolated the continuation (or the truncation) of the surface trace of mapped layers and structures between the area constrained by our field traverses. Dextral NW-trending wrench faults are the dominant structural feature between major thrusts; sinistral, probably conjugate faults are subordinate. Dextral displacements are typically up to a few 100 m, lengths are 12-50 km, and spacing is surprisingly constant. Generally, the wrench faults do not offset the thrusts - rarely they do and in these cases neotectonic features (e.g. fault scarps, sag ponds) indicate recent reactivation. Fault-slip analysis demonstrates that thrusts of all scales have a sinistrall oblique-slip displacement vector. In aggregate, we interpret the structural geometry and kinematics to outline a sinistral transpressional belt, shortened ~NE-SW, in which fault-bound blocks rotated anticlockwise in domino-style, delimited by sinistral oblique thrusts trending subparallel to the Kun Lun belt. This structural interpretation holds from outcrop to map scale. Building on the post ~10 Ma growth model of the Tibetan plateau of Meyer et al. (1998), which invokes NE-ward growth along a sinistral oblique thrust belt delimited by the Altyn Tagh strike-slip belt, our data for the DGC belt indicates that a similar mechanism might have been active during the Tertiary. Current research focuses on the age of DGC deformation, deposition, and source region exhumation. Together with other Cenozoic red bed areas the DGC will provide a key indication of how strain was focussed, switched loci, and reactivated mechanical instabilities throughout the evolution of the Tibet plateau.

T62D-13 1345h POSTER

Timing and Rates of Late Neogene Extension in Central Tibet

Peter M Blisniuk[1] (+49-331-977-5405; blisniuk@rz.uni-potsdam.de); Ken Ludwig[2]; Warren Sharp[2]; Rick Ryerson[3]; Leslie J Sonder[4]; Siwen Bi[5]; Zhenhan Wu[5]; Lothar Ratschbacher[6]; Mike Edwards[6]

[1]Institut fuer Geowissenschaften, Universitaet Potsdam, Postfach 601553, Potsdam D-14415, Germany

[2]Berkeley Geochronology Center, 2455 Ridge Road, Berkeley, CA 94709, United States

[3]LLNL, University of California, P.O. Box 808, Livermore, CA 94551, United States

[4]Dartmouth College, Fairchild Science Center, Hanover, NH 03755, United States

[5]Chinese Academy of Geological Science, 1, Beijing, China

[6]Universitaet Freiberg, Bernhard-von-Cottastr.2, Freiberg D-9596, Germany

The tectonic and topographic evolution of the Tibetan Plateau are of fundamental importance for both, tectonic models of collision-related deformation as well as global climate models. However, the geologic data base for the plateau area is limited due to difficult logistics, and as a result the plateaus evolution is still poorly understood. Published efforts to constrain the timing of plateau uplift focus on studies of the late Neogene extension of the plateau, which is generally considered to be a direct consequence of plateau uplift. To date, the few available data favor a middle to upper Miocene age, probably between 9 and 7 Ma, for the onset of extension in southernmost Tibet. In contrast, farther north in the Shuang Hu graben of central Tibet the onset of extension has been estimated to be no older than 4 Ma, based on extrapolation of late Quaternary fault slip rates derived from fault scarp degradation modeling. The scarp profile and model parameters are, however, poorly constrained, so this result, although representing the best possible interpretation of the available data, should be viewed with caution. To better constrain the Quaternary rates of subsidence and extension in central Tibet, we have surveyed and quantitatively modeled elevation profiles of fault scarps offsetting 4 particularly well-preserved terrace surfaces along the margins of the Shuang Hu graben. Additional age constraints are provided by first results of ongoing cosmogenic nuclide and U/Th dating of two of the terraces. Our preliminary results indicate that the late Quaternary slip rates along the margins of the Shuang Hu graben are significantly smaller than those estimated by previous workers. Correspondingly, extrapolation of these rates back in time results in substantially older age estimates for the onset of extension in central Tibet, although the soundness of this extrapolation is questionable. In contrast, our first results suggest that the combination of fault scarp degradation modeling with absolute age determinations of the displaced terrace materials will result in reliable slip rate estimates for late Quaternary normal faulting in central Tibet, and create the potential to apply linear diffusion modeling to estimate fault scarp ages on the Tibetan Plateau with reasonable accuracy.

T62D-14 1345h POSTER

Colorado Plateau Uplift: Constraints From a Plaeoaltimeter based on Vesicular Basalts

Dork Sahagian[1] (603 862 3875; gaim@unh.edu)

Alex Proussevitch[1] (603 862 4796; alex.proussevitch@unh.edu)

[1]EOS and ESci, UNH, Morse Hall, Durham, NH 03824, United States

The problem of epeirogenic plateau uplift, particularly of the Colorado Plateau, has been an issue of concern for many decades. We have recently developed new techniques for independently measuring paleoelevations on the basis of the vesicularity of lava flows. We are presently applying these techniques to determine the timing and extent of Cenozoic uplift of the Colorado Plateau. A definitive understanding of uplift history would shed light on outstanding issues in paleogeography, paleoclimatology, geomorphology, lithospheric stress and deformation, heat flow and thermal structure, and mantle processes. Because our recently developed technique measures paleoatmospheric pressure, it is not subject to uncertainties stemming from the use of proxies which depend on factors other than elevation alone.

Yet another possibility is tribochemical weakening at high velocities (e.g., Hibi and Enomoto, 1999). This weakening is due to the formation of metastable phases at the asperity interfaces, and the weakening distance is probably controlled by the reaction rate forming the phases (enhanced by the frictional heating). Direct evidence for such processes will be difficult to find in natural fault zones because the phases are metastable.

Among above cases, the first stages of weakening due to flash temperature and tribochemical weakening may be the most significant along natural faults. The former and the latter would be important under dry and wet conditons, respectively. Both cases should be throughly studied experimentally to evaluate their significance. High velocity hydrothermal rig in Kyoto will be used for such studies.

T62D MC: Hall D Saturday 1345h

Raising Plateaus IV Posters *(joint with G, GP, S, V)*

Presiding: **G Wittlinger,** EOST, UMR CNRS-ULP; **M Strecker,** University of Potsdam

T62D-01 1345h POSTER

Limits of Lateral Plateau Growth and Ephemeral Sedimentary Basins at the Eastern Puna Margin, NW Argentina

Manfred R. Strecker[1] (strecker@geo.uni-potsdam.de)

R. N. Alonso[2]

K. Haselton[1]

G. E. Hilley[3]

M. Trauth[1]

[1]Inst. f. Geowissenschaften, Univ. Potsdam, Potsdam 14415, Germany

[2]Univ. Nac., Salta, Salta 4400, Argentina

[3]Dept. of Geology, Arizona State Univ., Tempe, AZ 85287, United States

Although situated in a non-collisional geodynamic setting, the Southern Central Andes host much of the second largest orogenic plateau on earth. One of the striking similarities between the Andean Puna and the Tibetan Plateau are overfilled sedimentary basins resulting from the tectonic and hydrologic isolation of former foreland basins that became infilled and incorporated into the plateau. However, in contrast to more arid northern Tibet, growth of the Puna is limited, as shown by the history of arid intramontane basins in the transition of the Puna to the Eastern Cordillera (EC) and the NW Sierras Pampeanas basement uplifts. Despite their location at high elevations, surrounding high ranges, and an identical tectonic style with respect to the neighboring Puna, the internal drainage and onlap of sedimentary fill onto basin boundaries are ephemeral. An undisturbed infill and successful incorporation into the plateau realm is inhibited by headward erosion and breaching. The close proximity of an orographic barrier concentrates precipitation on its windward side, causing large rainfall gradients and high stream erosion resulting in drainage capture and ultimately basin exhumation. A prime example for studying the transient nature of these basins is the intramontane Qda. del Toro basin at ca. 24 S lat. Located at the eastern Puna border within the EC, this basin shows the transition from a former foreland to a broken foreland basin with range uplift after about 8 Ma. The deformed sediments are overlain by about 1000-m-thick poorly lithified conglomerates; in the lower 200 m of the section these laterally grade into lacustrine deposits. The lacustrine strata bear plant fossils indicating a humid environment similar to the eastern windward slopes of the present basin border. Deposition of these units began well after deformation of the 8 Ma conglomerate but before deposition of a 4.17 Ma tuff in the lower part of the sequence. Conformable deposition of conglomerates continued until 0.98 Ma, when renewed thrusting along the basin margins and within the basin itself deformed these strata. These deposits were incised to elevations comparable to the present base level, suggesting integration of the Toro basin into the foreland drainage system. However, this event was superseded by a second, important influx of conglomerates. These undated Quaternary conglomerates filled the pre-existing erosional paleo-topography to levels that are up to 700 m above the present trunk stream and must have been stored in the basin at least until mid-Pleistocene time. Subsequently, these conglomerates and all previously deposited units were extensively stripped and incised again to the present local base-level. Incision took place episodically as documented by five inset strath terraces that follow the course of the trunk stream. The episodicity of downcutting and exhumation of paleo-topography is underscored by the association of some terraces with landslide debris and lacustrine units related to temporary damming of the narrow gorge that forms the basin outlet into the adjacent foreland areas. Similar histories exist in other basins along the Puna edge. Despite favorable tectonic conditions, asynchronous eastward migration of deformation, and creation of isolated sedimentary basins, the basins east of the Puna are clearly transitory. In contrast to basins within the much more arid Puna the basins in NW Argentina cannot be sustained as closed basins due to the more effective erosional regime of a wetter climate.

T62D-02 1345h POSTER

Tertiary Synorogenic Deposits of the North-Central Altiplano Plateau, Bolivia: Implications for Erosional History of the Central Andes

Brian A. Hampton[1] (225-388-2337; bahampt@lsu.edu)

Brian K. Horton[1]

[1]Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803, United States

A thick succession (>9000 m) of nonmarine deposits in the north-central Altiplano plateau of Bolivia contains stratigraphic evidence for the erosional history of the Central Andes. Measured stratigraphic sections, paleocurrent determinations, sandstone petrography, and preliminary flexural modeling indicate substantial sediment accumulation associated with erosion of both the west and east flanks of the present-day plateau (the Western Cordillera and Eastern Cordillera, respectively). Measured sections from the east limb of the Corque syncline and areas south of the syncline (17.5-18.5S, 67-68W) show a vertical transition from marginal marine and lacustrine, 275-m-thick Upper Cretaceous-Paleocene strata (upper El Molino, Santa Lucia and Cayara Formations) to fluvial, 9000-m-thick upper Eocene-lower Miocene deposits (Potoco and Totora Formations). Paleocurrent and petrographic data from the lower ~4000 m of the Potoco Formation indicate deposition of tabular, laterally extensive beds of fine-grained sandstone and siltstone derived from the west. These strata contain increasing amounts of granitic and volcanic detritus upsection, probably derived from Precambrian crystalline basement and Tertiary volcanic rocks in the Western Cordillera. The overlying ~5000 m of Potoco and Totora strata contain tabular, laterally extensive beds of medium-grained sandstone and siltstone derived from the east and northeast. East-derived strata contain no Precambrian detritus due to unroofing of only Paleozoic-Mesozoic strata in the Eastern Cordillera. Northeast-derived strata contain lesser amounts of granitic and volcanic detritus which may imply a depositional phase of axial drainage in which sediment derived from both the west and east reached the Corque syncline area. Given the exceptionally thick nonmarine succession, thermal subsidence can be excluded as the sole cause of basin subsidence. Preliminary flexural modeling is constrained by a reconstruction of basin dimensions (maximum stratigraphic thickness, lateral thickness variations, possible forebulge location) for Tertiary strata in the north-central Altiplano. Although reasonable flexural profiles can be produced using a range of elastic thicknesses, the distribution of ancient topographic loads to the west and east remain poorly known. We attribute the sediment dispersal patterns, sediment accumulation history, and flexural modeling results to deposition in a nonmarine sedimentary basin influenced in part by flexure due to topographic loading in the Western Cordillera (related to early-mid Tertiary shortening) and Eastern Cordillera (related to mid-late Tertiary shortening).

T62D-03 1345h POSTER

Some Consequences from the Temperature-Heat-Paradox in the Altiplano (Central Andes)

Peter Giese[1] (++49 30 838 70 800; giese@geophysic.fu-berlin.de)

Frank R Schilling[2] (++49 331 288 1875; fsch@gfz-potsdam.de)

[1]Departement of Geology and Geophysics, FU Berlin Malteserstr. 77-100, Berlin 12249, Germany

[2]GFZ-Potsdam, Telegrafenberg, Potsdam 14473, Germany

In the Altiplano the mean heat flow density is at least 90 mW/m^2. Hence, classical conductive backwards geothermal modelling of the Altiplano with its 70km thick crust yields unrealistic high temperatures of more than 2500^{o}C at the crust-mantle boundary. On the other hand all 2D thermal forward models for the Altiplano give heat flow density values lower than 70 mW/m2: the Altiplano temperature-heat-paradox. Additional heat transport mechanisms are necessary to explain the observations. A number of geophysical, geological and petrological constraints may help to develop more realistic geothermal models. The most important observations are: An extremely high electrical conductivity below 20 km depth associated with high $v_P/_S$ ratio and a strong absorption of seismic energy (low Q) in the same depth range suggesting the existence of partially molten rocks; a strongly laminated seismically reflective crust in the depth level 20 - 30 km; crustal thickening from 30 - 40 km to 70 km in the last 20 Ma associated with an uplift of about 3 - 4 km, and volcanic activity over the last 20 Ma.

We use the temperature-heat paradox to estimate advective heat transport in deeper crustal levels and the release and consumption of latent heat by cooling of magmatic intrusions and partial melting of the surrounding rocks. The order of magnitude of the mass influx (advective heat transfer and latent heat release) can be estimated by using geophysical observations. The surface heat flux of 90 mW/m can be interpreted as caused by radiogenic heat generation of 35 mW/m^2 and a basal heat flux of 25 mW/m^2 resulting in the 60 mW/m^2 known from forward modelling. In addition to this conductive heat transfer a latent heat release/advective heat transfer of $\sim$ 30 mW/m^2 is necessary to explain the observations, resulting in a mass flux of $\sim$ 0.9 mm/a of mantle material into the crust. The consequences of these rough estimates over a time span of 20 Ma result in a crustal thickening by magmatic intraplating of $\sim$ 18 km associated with an uplift of about 2.8 km. Our modelling results suggest that advective heat transfer and latent heat release in deeper and middle crustal levels strongly control the temperature field and the evolution of the Central Andean Altiplano region during the past 20 Ma.

T62D-04 1345h POSTER

Thermomechanical Modeling of Large-Scale Melting in the Middle Crust in the Altiplano-Puna Plateau

Andrey Yu. Babeyko[1,2] (+49-331-2881264; babeyko@gfz-potsdam.de)

Stepan V. Sobolev[1] (+49-331-2881248; stephan@gfz-potsdam.de)

Robert B. Trumbull[1] (+49-331-2881495; bobby@gfz-potsdam.de)

Luc Lavier[1] (+49-331-2881342; lucl@gfz-potsdam.de)

Onno Oncken[1] (+49-331-2881310; oncken@gfz-potsdam.de)

[1]GeoForschungsZentrum-Potsdam, Telegrafenberg E3, Potsdam 14473, Germany

[2]UIPE-Moscow, B.Gruzinskaya 10, Moscow 123810, Russian Federation

Among the first-order observations of the Altiplano-Puna plateau which needs to be explained by any model for plateau formation is the mid-crustal zone of low seismic velocity (Andean Low Velocity Zone ALVZ) which extends across the entire plateau at ca. 20-25 km depth. The most pronounced part of the ALVZ correlates with the major ignimbrite province of the Altiplano-Puna Volcanic Complex, and there is good evidence that both features reflect crustal melting. Since the ignimbite activity is correlated in space and time with the late Miocene plateau, crustal melting and the ALVZ appear to be related to the plateau-building process.

Foremost among the geologic constraints on crustal melting in the ignimbrite province are that well over 10000 cubic kilometers of silicic magma were erupted within 5 My, some 10-15 My after plateau initiation. The ignimbrite magma had pre-eruptive temperatures of at least 800^{o}C and was hybrid, comprising some 70% crustal melt and 30% arc andesite. The problem we address with thermomechanical numerical experiments is how melting temperatures can be achieved in the middle crust within only 10-15 My after initiation of plateau formation.

We present model results which explore two potential heat sources for melting in the ALVZ: (1) internal, by shear heating and/or radiogenic heat production related to tectonic shortening; (2) external, by intrusions of arc andesite magmas. We show that scenario 1 results in a temperature rise of less than some tens of degrees within the time constraints. Scenario 2 would require intruding nearly all arc magmas into the mid crust unless ambient temperatures in the melting zone are elevated by other means. Our modeling suggests that the other process could be advection of heat from hot, possibly partially molten, lower crust. The necessary condition for this advection is a low crustal viscosity, which could be achieved by a combination of felsic bulk composition and high strain rates due to deformation.

Crustal melting under the Altiplano-Puna plateau developed relatively rapidly because of a combination of tectonic effects of plateau formation and heat input from an active magmatic arc. We suggest that the arc magmatism accelerated a process, which might have occurred later from plateau-building alone. Crustal low-velocity zones like the ALVZ are also observed in the

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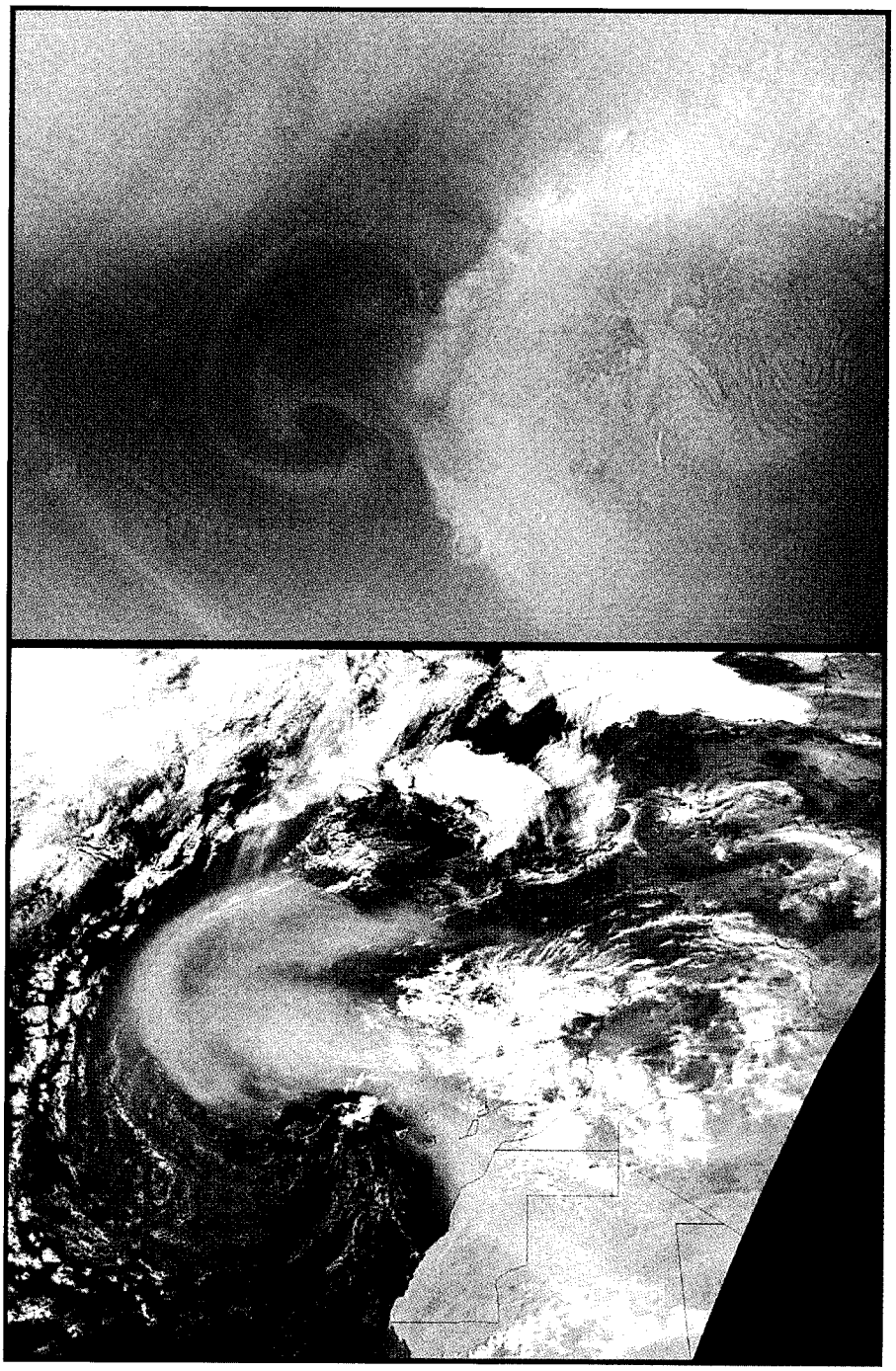

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